Mobile technology and mathematics

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Effects of using mobile technologies with mathematics

Introduction

The use of technology in mathematics education has been highlighted by researchers over the past two decades. In the US, the National Council of Teachers of Mathematics (n.d.) considers technology as "essential in teaching and learning mathematics. (p. 3)." Scotland's Curriculum for Excellence (n.d.) notes that "use technology in appropriate and effective ways (p.40)" allows for learning experiences that promote the enjoyment of mathematics. In a survey of mathematics research over the past 30 years, Cheung and Slavin (2013) found that technology produced a positive effect on students' achievement in comparison to traditional methods. However, they also indicated that effects varied by the type of educational technology used. Mobile technologies have been gaining wider acceptance in education in the recent years with schools and government level initiatives that plan to roll out these technologies in the classroom (West, 2012). Potential benefits of using mobile technologies for learning include: bridging pedagogically designed learning contexts, facilitating learner-generated contexts and content and providing personalisation in both personal and collaborative environments (Cochrane, 2010).

Reports on the use of mobile learning in mathematics

Mobile technologies have provided various approaches to learning: engaging learners in contextualised learning environments using the plethora of sensors built-in on these mobile technologies (Tangney, Weber, Knowles, Munnelly, Watson, Salkham and Jennings, 2010) using the mobile phone to journal math learning (Project Tomorrow, 2011); and connecting learners through mobile phones and social media (Roberts, 2009).

Crompton & Burke's (2014) survey of mobile learning in mathematics showed that there is a growing interest in terms of its effectiveness and that 75% out of the 48 studies reported positive learning outcomes. However, this number is rather small in comparison to the amount of research that utilised other existing educational technologies like computers and calculators. Similarly, in Fabian, Topping and Barron's (2014) review of mobile learning studies on mathematics 77% of 31 studies reported that mobile technologies improved students' achievement. An effect size of 0.48 was also reported for elementary studies.

Pollara & Broussard (2011) noted that majority of studies on mobile learning reported that students have positive perceptions of its use in the classroom. Similarly, mobile learning studies on mathematics yielded the same results where students found the use of mobile technologies engaging and useful (Kalloo & Mohan, 2011; Kong, 2012; Huang, Wu, Chen, Yang, & Huang, 2012; Lai, Lai, Shen, Tsai, & Chou, 2012). Baya'a & Daher (2009) reported that students see mobile technologies as useful mathematics tools because it facilitates visualisation, encourages collaborative learning and enables exploration of mathematics in outdoor environment. However, like the math and mobile learning studies noted above, much of current studies on mobile learning are short term implementations so it was not possible to note how students perceive the use of mobile technologies over long term use.

Student attitude, achievement and the relationship between the two is a well-researched area (Zan, Brown, Evans and Hannula, 2006; Huang et al., 2011). However, the effect of technology use to attitudes towards mathematics forms a body of limited literature (Li and Ma, 2010) and this is also the case with mobile technologies. Quantitative studies that investigate the effect of using mobile technologies to students' attitude towards mathematics are limited. A literature search from 2003-2014 yielded only six relevant studies but results from the six studies varied. Three studies found a change in student self-concept and attitudes to maths (Main & O'Rourke, 2011, ES =.66; Riconscente, 2013,, ES = .42 - .47; Chang & Wu and Sung, 2006, ES not avaialble) and three studies (Jaciw, Toby, & Ma, 2012 ES not available; Miller & Robertson, 2010, 2011, ES not available) found otherwise. The implementation of mobile learning activities varied for the six studies ranging from one day to one year. This limited and differentiated results on this aspect of maths learning is a gap in mobile learning literature and one that this current study addresses.

Design framework

Effective technology integration requires consideration of the technology and pedagogy. Drijvers (2012) pointed out that design, the role of the teacher, and educational context are crucial elements in integrating technology for mathematics. Sawaya & Putnam (2015) proposed an integrated framework for the design of mobile learning activities. This considers: (a) learning goals, (b) activity types and (c) affordances of the technology in reference to what mobile devices offer to support mathematics learning. A representation of the framework is shown in Figure 1. These technology affordances are not unique to mobile devices but it is the combination of these affordances in a single device that highlights the potential of mobile technologies in supporting various learning activities.

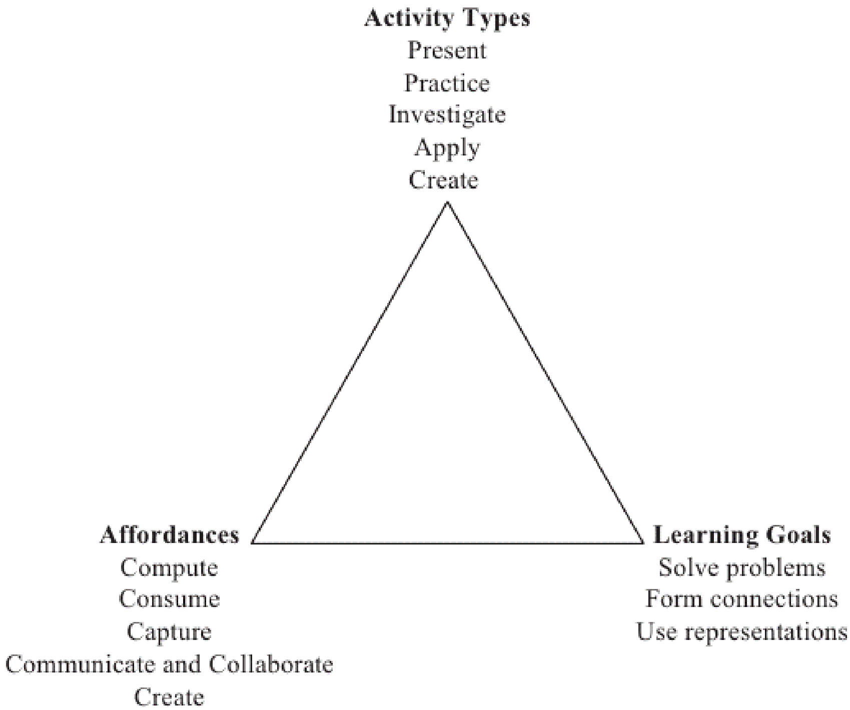

Figure 1: Framework for the design of mobile learning activities for mathematics (Sawaya and Putnam, 2014)

One of the noted advantages of mobile technologies over traditional computing is its capacity to support learners in a variety of context (Tangney et al., 2010). Through the ubiquitous learning environments that mobile technologies support, learners are afforded the chance to learn in-situ (Baya'a and Daher, 2009; Kurti, Spikol and Mildrad, 2008). In these learning environments, students have found the use of mobile devices interesting and helpful in terms of facilitating visualisation of maths concepts. However, most of these studies have been in the exploratory stages and qualitative by design. Studies that provide evidence in terms of improvement in student performance are few (Chang et al., 2006, Huang et al., 2012; Shih, Kuo and Liu, 2012) so this features that our study design adopted.

Applying Sawaya and Putnam's (2014) design framework and the concept of ubiquitous learning environments, the various activities in this intervention all have the goals of making students connect mathematics concept to their environment by harnessing the affordances of mobile devices to capture and create information as students engage in the activities.

Research Questions

Given the limited literature that explores the effects of using mobile technologies in mathematics, it is the goal of this research to further investigate the effects of using mobile technologies to students' attitude and achievement. Specifically, this study aims to answer the following research questions:

a) What are the students' views on the use of mobile technology for learning Mathematics?
b) Is there a change in attitude towards mathematics when mobile technology is used for learning math
c) Is there a change in attitudes towards technology when mobile technology is used for learning mathematics?
d) Is there an improvement on mathematics achievement when using mobile-supported math learning activities?

2. Methodology

2.1 Research design

The study adopted a quasi-experimental mixed methods design. Evaluation is carried out in three levels: Micro, Meso and Macro-evaluation (M3) using Vavoula & Sharples (2011) evaluation framework. The M3 level evaluation framework provides "structured format to assess usability, educational and organisational impact and their inter-relationships (p. 12)." The micro-level evaluation focused on the user evaluation of the mobile-supported activity. At meso level, evaluation focused on the learning experience. At macro level, evaluation focused on how the use of the mobile device affected students' attitudes towards mathematics.

2.2 Participants

The participant classes were obtained by soliciting voluntary self-selected teachers from within one local authority in Scotland. Two teachers participated as session leaders for the mobile learning intervention. One is a female teacher with five years of teaching experience (School 1) the other is a male teacher with 11 years of teaching experience (School 2). The student participants were the students assigned to the teacher participants of this study. A total of 82 primary 6 and 7 students between 9-11 years old participated in the study with 48 (23 boys and 25 girls) students in the tablet group and 34 students in the control group (15 boys and 19 girls).

2.3 Instruments and measures

2.3.1 Technology used

The mobile device used in the study were budget 7-8 inch tablets of various brands all running Android 4.2 all costing less than £100 each. The rationale for the choice of smaller tablet over the bigger 10-inch screens is because of its portability as a number of activities are carried out while students move around whilst the 7-8 inch screen size allows two users to conveniently share a screen.

2.3.2 End activity evaluation.

The End-Activity Evaluation Questionnaire consists of 18 adjectives derived from Microsoft Desirability Toolkit (Benedek & Miner, 2002) and three questions from Lewis, (1991) After Scenario Questionnaire. The questionnaire was designed to allow the students to rate the activity and the tablet separately. Responses were arranged on a semantic differential scale with two opposite adjectives and grouped in three factors: usefulness, ease of use and user satisfaction.

2.3.3 Focus group discussions.

Focus group discussion was designed to elicit student feedback about the activities which might have been missed in the end activity survey. Students recapped the activities that they had done so far and were asked to explain which of the activities they liked and least liked. Their opinion as to what the advantages and disadvantages of doing these types of activities was were also sought. Students also related the challenges they had experienced with the activities. Discussions were audio recorded and transcribed.

2.3.4 Maths Attitude Inventory (MAI).

The maths attitude inventory used in this study was adapted from two maths inventories 15 questions from Lim & Chapman's (2013) Attitudes Towards Mathematics Inventory and five questions from Pierce, Stacey, & Barkatsas's (2007) scale to measure students attitudes to mathematics when technology is considered. The resulting inventory had 5 subscales: (1) enjoyment of mathematics, (2) self-confidence, (3) value of mathematics, (4) confidence with technology and (5) learning mathematics with mobile technology.

2.3.5 *Math test* (MT)

The math test consisted of 10 questions with a maximum score of 40. The questions included items on symmetry, angles, area and perimeter and information handling. So where did this come from? These items were derived from practice exercises in Primary 6 and 7 mathematics books. What was its reliability and validity? What was the rationale behind its construction **2.4 Procedure**

At the start of the intervention, participants of the control groups and the tablet group completed MT and MAI. Following the tests, an introductory session was also conducted to brief the participants about the nature of the activities that will be carried out.

The tablet group participated in eight hour-long sessions of mobile learning activities spread over a period of three months. The sessions were collaborative and covered topics on angles, symmetry and information handling. The activities were split into indoor (Phase 1) and outdoor activities (Phase 2). Students completed an End Activity Evaluation questionnaire at the end of an activity. At the end of phase 1, the tablet group completed the same MAI test from pre-test. Students then went on a two weeks spring break. Phase 2 started just after the break and included mostly outdoor activities. At the end of Phase 2, both the tablet and control group retook the math test and MAI. A focus group discussion with the tablet group was also carried out at the end.

2.4 Data analysis

2.4.1 Micro-evaluation.

The ratings on the end activity evaluation were grouped into three categories: usefulness, ease of use and user satisfaction. These are further grouped into tablet and activity ratings. The usability of the tablets were analysed using the descriptive statistics. Gender differences on how students perceived each activity were also examined via an independent t-test between male and female ratings.

2.4.2 Meso-evaluation.

Student perceptions about the learning experience were analysed from the focus group discussions. Student responses to the questions raised in the focus group discussions were analysed into themes: 1) student perception of the tablet activities, 2) the advantages/disadvantages of using the tablets, 3) opinion on group/paired work and 4) issues and challenges in using tablet devices.

2.4.3. Macro-evaluation

Macro-evaluation included the MAI and MT pre-test, post-test and final test scores of the control group and the tablet group. At independent t-test was conducted to compare the tablet and control group at pre-test. To compare how the groups performed after the intervention, an independent t-test on the difference between post and pre-test was conducted.

Comparisons were also made based on gender and student performance. For MAI, gender difference was conducted via an independent t-test of the gain scores for each MAI subscale. This was only done for the tablet group as the goal was to check if the use of the tablet has resulted to any gender difference. Gender difference in gains in MT score of the tablet and control group was examined using an analysis of variance. To group the students by their performance, MT pre-test score was ranked then split into two groups, low MT which is the lower half and high MT which corresponds to the higher half. To check whether the changes in pre-test and post-test scores were significant, a paired t-test was conducted for each group. To compare whether there was a difference in gains based on initial student performance on MT, an independent t-test on their gain scores in MT was conducted.

Lastly, to look for differentiations between the participants of the two schools, an independent t-test of the gains in MT and MAI was conducted.

3. Results

This section is divided into the three evaluations carried out in this study: 1) micro-evaluation that corresponds to the tablets' usability test; 2) meso-evaluation which represents the student evaluation of the learning activities; 3) macro-evaluation which covers the quantitatively measured effects of using the tablets on students' attitudes and achievement

3.1 Micro-evaluation

A graph of the semantic differential ratings for the evaluated sessions is shown in Figure 1. All negative items were reversed scored such that all negative items are on the left and positive items are on the right. A higher score mean agreement with the positive statement while a lower score means otherwise. For example, in the activity with areas and perimeters, an average rating of 4.0 in the item irrelevant vs useful meant that students found the activity more useful rather than irrelevant. From the graph, it can be observed that most of the activity ratings fall within the positive ratings with a range between 2.6 and 4.5. Of the total 5028 item responses, 81% of the ratings fall above 2.5 and 17% below that. This means that majority of the students evaluated the activities positively.

Figure 1. End activity rating

The end activity ratings in Figure 1 were grouped into three subscales of usability: usefulness, user satisfaction and ease of use. The items were also grouped into activity ratings and technology ratings. Each subscale score is the average of the item ratings for that category thus giving a range of score between 0 – 5. A high subscale score indicates a good usability rating and vice versa. The usability ratings for the tablet and the activity were all positively correlated except for the ratings on the usefulness subscale for the outdoor-based information handling activity; r(40) = .264, p = .095. This session had several technical issues and while the students' evaluation of the activity as useful (M = 3.74; SD = 1.06), their evaluation of the tablet's usefulness (M = 3.00; SD = 1.67) had been significantly different for this specific session; t(40) = 2.769, p = .008.

An independent t-test of the ratings by gender showed a higher rating from male students (M = 4.56, SD=.37) on the satisfaction subscale for tablets than female students (M = 4.05, SD = .82), t(21) = 2.384, *p* = .027 during the first activity but this difference however did not manifest in the later activities.

3.2 Meso-evaluation

3.2.1 Student perception of the tablet activities

Twenty-seven students provided feedback on the nature of the tablet activities. Of that sample, 67% had positive feedback, 17% with mixed feedback and 5% with just negative feedback. Students found the use of the tablets fun (n=11), makes learning easier (n=5), useful (n=3) and better than their usual maths lesson (n=3).

> *"I found that I understood it more. When the teacher describes something to you, I don't really get it [but with the tablets I understood it more] and it was really fun." (Maggie)*

A few students found the activity hard (n=2) because sometimes the technology doesn't work and because of that one student felt that it was better working with just normal pencil and paper.

> *"It was hard because sometimes they don't work." (Robert)*

Students with mixed feedback (n=7) found the activities fun but the technical issues encountered lessened the positive experience they had.

> *"It was good, and it was fun but sometimes the app didn't work and then you got annoyed." (Kathryn)*

> *"I like the tablets, it's just sometimes they're not working." (Joshua)*

Students who scored low on the maths pre-test found the activities easier (n=7) and more interesting (n=1). One dyslexic student explained that he found the activities easier because he normally finds it more difficult on paper.

> *"It is more interesting than sitting there with a pencil and working out problems." (Edith)*

Similarly, students who scored high on the maths pre-test found the activities fun (n=9), more engaging (n=2), better than their usual maths, helpful and easier.

> *"It makes you look forward to maths like i know that every 11 o'clock every Thursday I was gonna get good maths. No, not good maths... I mean more fun maths... better maths." (Marcus)*

In general, students have positive views about the tablet use but some technical issues had lessened their positive experience. Students who found maths difficult found the activities on the tablets easier while students who were already good with maths found the activities fun.

3.2.2 Perceived advantages/disadvantages of doing tablet activities

Students were asked what they thought were the advantages were and most of the answers were in relation to how they would normally do mathematics without these tools. Students felt that it was better than their usual maths lesson because it was more fun (n=9), engaging (n=6), more interesting (n=2), and more active, with the activities allowing them to move about and engage with their environment (n=2)

> *"It was really fun and also when I use the tablets I understood it more when I kept using it but when I just write it on a jotter, I still don't know what's happening." (Erica)*

However, some students (n=3) who experienced far more technical difficulties than the others were not too sure about the advantages. One of the disadvantages of the tablet is that it can behave unpredictably and when it does, there's the chance for the digital work to be corrupted and prompt the user to start from the beginning.

> *"If it doesn't work then all that you done is gone unlike when you're working with paper. If you've got sheets there will always be spares but with tablets you don't so you do it again, then you get bored of it." (Lorraine)*

Another disadvantage mentioned is that students can go off task (n=2) and most of the time, it happens when students experience technical issues that aren't addressed straight away.

3.2.3 Working in pairs and in groups

Some students who initially had low self-confidence scores had contrasting views when it comes to group work. Some students found working in groups harder (n=4) and it makes them miss out (n=2).

> *"I find it harder because some people don't share the tablet and you get missed out and won't get your turn." (Mark)*

While some students from this subset find working in groups or in pairs better (n=3) and easier (n=4).

> *"It was much easier because if you had ideas to reflect off your partner... if you get stuck you're not sitting there like (not knowing what to do) and you'll be more like... how do you do this." (Emma)*

In contrast, students who had high self-confidence scores at pre-test found working in groups better than working on their own (n=9) as it made the load easier (n=7) and that it brought about their confidence in working with other people (n=2).

> *"It was fun because when one is stuck I can just go and help them but when we do it with normal maths and paper it's like they go to the teacher and ask if it was right but on the tablets we just worked it out and help each other." (Barry)*

However, there were also negative feedback (n=3) about group work or collaborative work from students who have higher self-confidence scores as students felt that their partners can get in the way at times (n=2).

> *"It helped but then sometimes people can do all of it and not give the other person a shot. And it could also be the opposite way, if you really like it, you'd be bad at not giving the other person a shot. Sometimes when you're with someone who doesn't understand then you'd want to do it all and if you're with someone that does it all then it annoys you as well." (Kathryn)*

3.2.4 Challenges encountered

Several challenges were encountered during the intervention including internet, software, and battery issues.

The tablets were connected to a mi-fi 4G device rather than the school's network but this type of connectivity is not very stable and so sometimes causes tablets to be disconnected from the network. One student commented:

> *"A couple of the tablets won't link. I can't send it to the teacher. I'm sitting next to him and I can't send it." (Archie)*

In one outdoor activity where internet connection had been necessary to create augmented realities, students were finding it difficult to keep connected as they would sometimes wander off in non-connected areas. Students resolved this issue by moving the mi-fi device with them then passing on the device to another group once they have finished their task. Although the process of moving the wireless network solved the issue, this however caused a delay to some groups as they had to wait for the others to finish before they can get connected with the network and carry on with their work.

Sometimes the applications on the tablet would shut down for no apparent reason. Students dealt with this issue via troubleshooting the problem with the tablet which solves the issue most of the time.

> *"You've got to figure out a way to get it done. it's okay sometimes coz we got through it, you just have to turn your tablet on and off and then it works." (Barry)*

However, not all issues were possible to troubleshoot. For example, on an outdoor-based activity with angles, a pair of students were having several issues with two different tablets and so, rather than waste more time on the tablets, the teacher handed the students a camera to work on instead.

> *"Every time that I got a tablet the app would not work. I had to use a camera."(Bianca)*

Some of the issues with the responsiveness of the application had been dealt with but there were cases where the instability of the application left students frustrated as they lost the work that they did for the session.

Students felt that these technology issues are the downside of doing these tablet activities and sometimes when issues happen, some students were not too motivated to move forward with the activity for the day. This hesitation however is usually set aside by the next activity as students who had issues were again keen to work on the new activity.

3.3 Macro-evaluation

3.3.1 Difference between tablet group and control group in MT

The control group (M=25.64, SD=7.77) performed significantly better at pre-test in contrast with the tablet group (M=15.90, SD=8.63), $t(79)=-5.25$, $p < .0001$, $d=-1.18$.

To compare the gains in maths score during the intervention, a t-test of the difference in pre-test and post-test score was conducted. The differences in the pre-test and post-test scores for both the control and control group was normally distributed, as assessed by the Shapiro-Wilk's test ($p > .05$). Students from the tablet group gained significantly higher differences between their pre-test post-test scores (M = 5.13, SD = 5) than the control group (M = 2.76, SD = 5.26), $t(80)=2.062$, $p = .042$, $d=.46$. A plot of the difference in pre-test and post-test scores of the tablet and control group is shown in Figure 2.

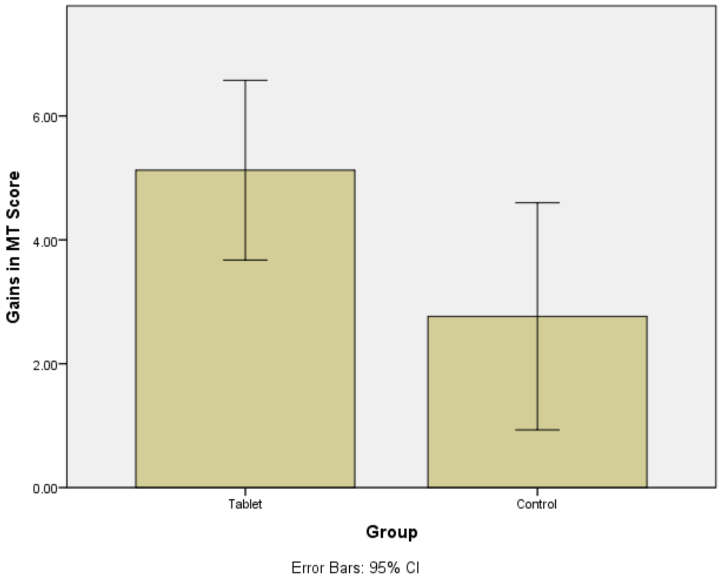

Figure 2. Difference between MT post-test and pre-test score of tablet and control group.

3.3.2. Gender differences in MT

An independent t-test of the pre-test scores by gender found no significant difference for both the tablet group, t(46) = .378, p = .707, d = .11, and the control group, t(32) = -1.10, p = .278, d = .38.

A graph of the differences in gain score is shown on Figure 3. From the graph, it is easy to note that female students in both the tablet and control group had higher gains in MT. There was no statistically significant interaction between gender and the groupings, $F(1, 78) = 1.508$, p = .223, partial $\eta^2 = .019$. However, there was a significant gender difference in the tablet group with female students having an MT gain score of 3.412 higher [95% CI, .54 to 6.28] than male students, $F(1, 78) = 5.601$, p = .020, partial $\eta^2 = .067$. For the control group, there was no gender difference found, $F(1, 78) = .143$, p = .706, partial $\eta^2 = .002$. Girls from the tablet group had a mean MT gain score of 3.707 [95% CI, .68 to 6.73] higher than their female counterpart in the control group, $F(1, 78) = 5.96$, p = .017, partial $\eta^2 = .071$. For male students, there was no difference in the gain scores of the tablet and control group $F(1,78) = .328$, p = .569, partial $\eta^2 = .004$.

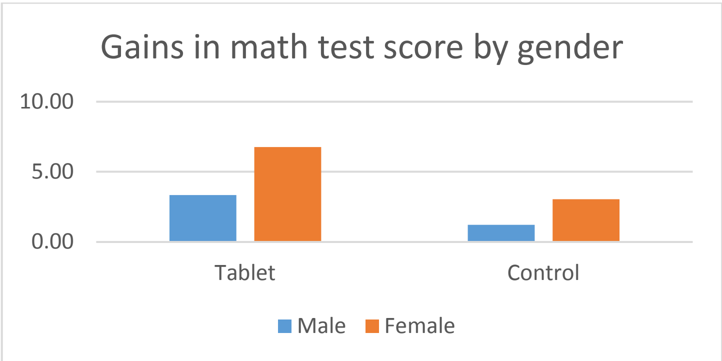

Figure 3. Gains in maths test score by gender.

3.3.3 Difference between low MT and high MT

Students' MT pre-test scores were grouped into high MT and low MT after a median split ranking. The gain scores by group are illustrated in Figure 4.

Following an analysis of variance, there was a statistically significant difference in the gains in math test score between the tablet and control group who belonged to the upper half, $F(1, 78)=4.74$, $p = .032$, partial $\eta 2 = .057$. For the lower half, there was no significant difference between the tablet and control group $F(1,78)=.795$, $p=.375$, partial $\eta 2 = .010$.

As for comparison of the gains of the low MT group against the high MT group, there was no significant difference found in either the tablet group, [$F(78) = .055$, $p = .816$, partial $\eta 2 = .001$] or control group [$F(78) = 2.114$, $p = .150$, partial $\eta 2 = .026$]. This indicates that the lower and upper half had the same rate of improvement in scores.

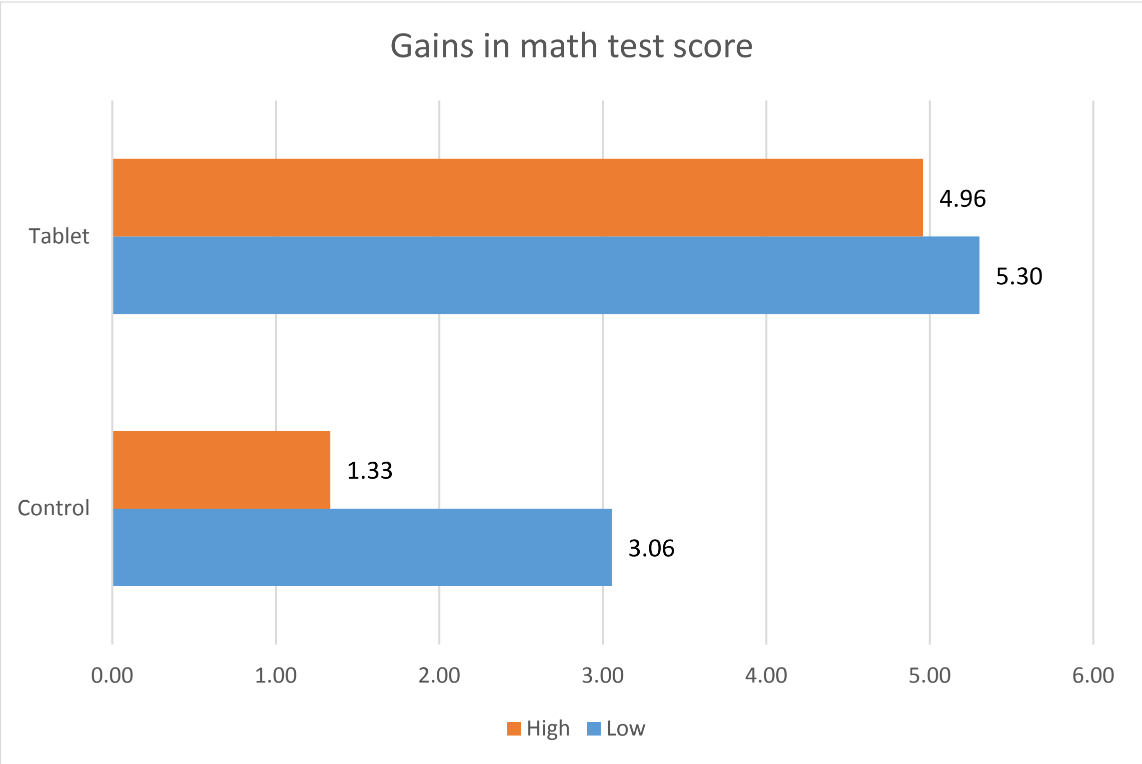

Figure 4. Gains in math test score of the low ranking and high ranking students

3.4 Mathematics Attitude Inventory

3.4.1 Change in MAI scores

Figure 5 shows the MAI scores for the tablet group in the three intervals. The descriptive statistics for Mathematics Attitudes Inventory (MAI) and its subscales is shown in Table 1. None of the paired t-test (pre-test with mid-test and pre-test with post-test) were statistically significant for both tablet and control group. An independent t-test of the MAI gains between the tablet and control group resulted in a significant difference in VMT, $t(80)=-2.001$, $p = .049$, $d=-.42$ favouring students from the comparison group. No other significant difference was found.

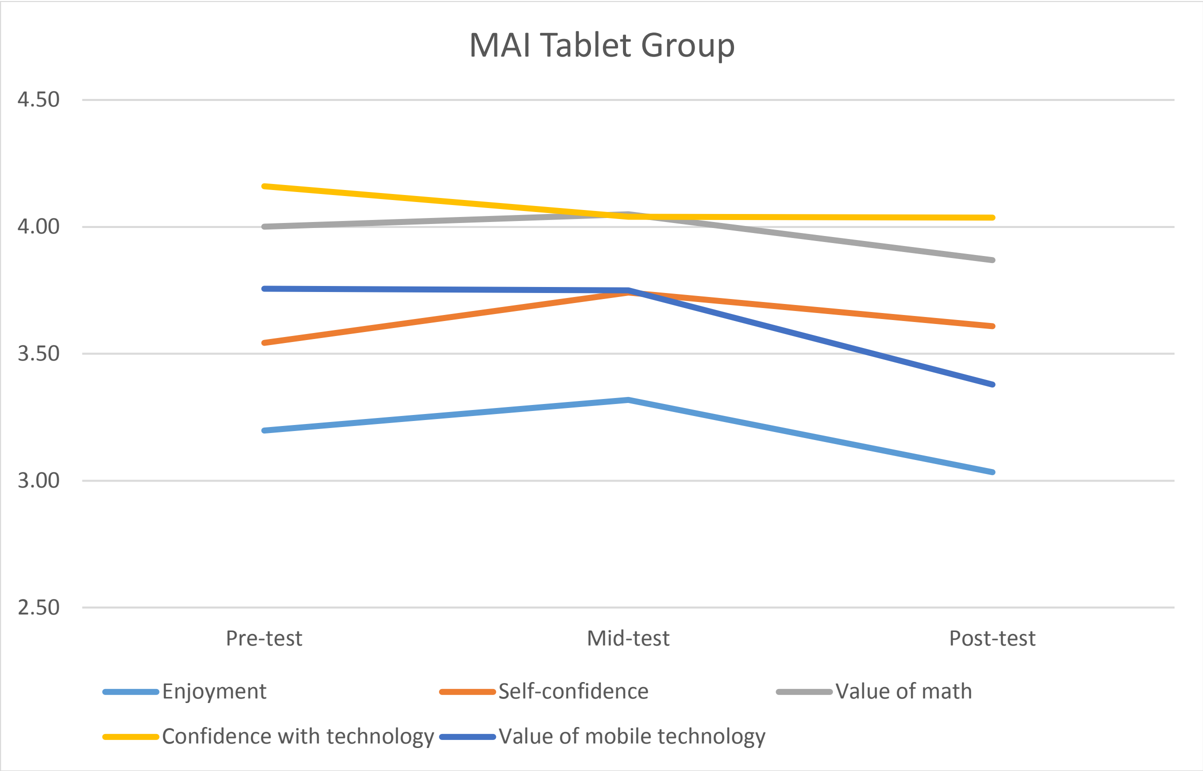

Figure 5. MAI scores of tablet group at pre-test, mid-test and post-test

Table 1. MAI scores of tablet and control group.

	Tablet Group (n = 48)							Comparison Group (n = 34)				Between group	
	Pre-test M (SD)	Mid-test M (SD)	Paired pre-test mid-test p-value	ES	Post-test M (SD)	Paired pre-test post-test p-value	ES	Pre-test M (SD)	Post-test M (SD)	Paired pre-test post-test p-value	ES	p-value	ES
Enjoyment (EN)	3.2 (1.22)	3.32 (1.36)	.431	0.11	3.03 (1.43)	.259	-0.16	2.7 (1.37)	2.49 (1.28)	.238	-.16	.831	.05
Self-confidence (SC)	3.54 (1.25)	3.74 (1.21)	.186	0.19	3.61 (1.16)	.693	0.06	3.46 (1.19)	3.35 (1.3)	.499	-.09	.471	.16
Value of Math (VM)	4 (0.94)	4.05 (1)	.710	0.05	3.87 (1)	.315	-0.15	4.17 (0.86)	3.95 (1.05)	.207	-.23	.663	.10
Confidence with technology (CT)	4.16 (1.03)	4.04 (0.99)	.265	-0.16	4.04 (1.03)	.386	-0.13	3.91 (1.06)	3.96 (0.98)	.743	.05	.414	-.18
Value of mobile technology (VMT)	3.76 (0.99)	3.75 (1.23)	.973	0.00	3.38 (1.37)	.109	-0.24	3 (0.99)	3.22 (1.2)	.252	.2	.049	-.42

3.4.2 Gender differences in MAI scores

There was no significant gender difference in EN, SC, VM and CT during pre-test. However, male students initially rated mobile technologies higher (M=4.09, SD=.88) than female students (M=3.45, SD=1.01), t(46)=2.319, p = .025, d=.67.

A comparison of the gain scores between male and female students in the tablet group during pre-test to mid-test and pre-test to post-test was conducted. There was a small gender effect on EN favouring male students (ES=.40) and a small gender effect of CT favouring female students (ES=.25) during mid-test. These gender effects were no longer observed at post-test.

3.5 Difference between School 1 and School 2

The implementation of the tablet programme had some differences between the schools in terms of programme fidelity, teacher and student characteristics. A t-test of the differences in pre and post-test scores is shown in Table 2.

Table 2. Difference in gain scores between schools.

	School				
	School 1	School 2	*t*	*df*	effect size *d*
MT	3.17(4.34)	7.08(4.92)	-2.93**	46	-0.84
EN	0.06(0.91)	-0.39(1.05)	1.58	46	0.46
SC Gains	0.27(1.33)	-0.14(0.89)	1.25	46	0.36
VM Gains	-0.13(1.14)	-0.13(0.59)	0	35	0
CT Gains	-0.57(0.78)	0.33(0.96)	-3.56***	46	-1.03
VMT Gains	-1.06(1.57)	0.31(1.34)	-3.25**	46	-0.94

Note. ** p < .005, *** p < .001. Standard deviations appear in parentheses.

It can be observed that School 1 had considerably decreased their scores relating to CT and VMT but it is also worth noting that their initial evaluation for CT (M=4.56, SD=.82) and VMT (M=3.95, SD=.876) are high. School 2, have minimal gains in CT (ES=.34) and VMT (ES=.23).

4. Discussion

4.1 Summary

Results at micro-level has shown that students rated mobile technologies positively. However, these results do not explain the decline in how they perceived the usefulness of mobile technologies for maths. A further scrutiny of the VMT and CT scores showed that there were differences between the results of the two schools that participated in this study.

The divergent data from the two schools tallies with the results derived from the interview data. In fact the mixed and negative feedbacks that were discussed in the earlier section were majority from School 1. Students from School 1 explained that they like using the tablets but sometimes it does not work and this is reflective of their post-test scores. As for students in school 2 where majority of the positive feedback from the interview was derived, students explained that they found the activities with the tablet fun and interesting and in ways better than traditional mathematics.

There was no change found in students' enjoyment of mathematics for the whole group although in the interview, students indicated that they enjoyed the activities with the tablet. A comparison of the individual interview data with MAI showed that the interview results corroborate with the individual EN findings of the MAI scale with some students but not for all. For instance, several students explained that they found the activities fun and this is evidenced by the gains in EN score. However, there were cases where the students explained that it was more fun and interesting but doesn’t translate to EN scores.

Students in the tablet group had a small positive improvement in their self-confidence with mathematics. The control group on the other hand a small negative decline. This increase in self-confidence is also apparent in some of the student narratives as they explained how the use of the tablets made them understand abstract concepts.

As for students perceived value of mathematics, both the tablet and control group had a small decrease in their VM scores although the decrease in the control group is slightly more than the tablet group. This decrease was not statistically significant. None of the interview data has mentioned students’ perceived value of mathematics so no data supports this findings. Despite this slight decrease, students still consider mathematics as important.

In terms of validating interview responses with MT gains, some students explained that the activities made them recall the topics better and this claim is supported by the increase in students’ math test scores particularly for those students who belong to the lower half of MT pre-test.

4.2 Interpretation of findings

In the succeeding paragraphs, we discuss the responses to the research questions using the results from the micro, meso and macro-evaluations and interpreting these findings in relation to existing literature.

4.2.1 What are the students’ views on the use of mobile technology for learning Mathematics?

In general, students have a positive view about the use of mobile technologies and they found the learning activities fun, engaging and useful. This positive result in students’ perception of mobile technologies is consistent with other mobile learning studies (Lai et al., 2012; Kalloo and Mohan, 2012).

Previous studies that report on student perspectives on the use of mobile technologies doesn’t separate evaluation of the activity or the tablet usability. For example, in Lai et al. (2012) the students found the use of the tablets easy and fun it was unclear whether students were also referring to the learning strategy used brought about by the tablets. While there was an attempt to separate the ratings between technology and activity, the positive correlation between the two suggests that students might not have objectively evaluated separately. Only in the most apparent technical issues did the students draw a line between the activity ratings and the tablet ratings

Gender difference was present in the initial activities but did not manifest in further end activity evaluations. While gender differences is a recurring issue in maths and ICT studies, a possible explanation for the lack of difference here is the exposure of participants to tablets and similar devices in their own homes.

As with other mobile learning studies (Kong, 2012; Lai et al., 2012), novelty was a contributing factor to student satisfaction. Students contrast the mobile learning activities with what they usually do and although challenging to some students, students' satisfaction with the activities have remained positive. However, not all students are secured with handling technology and some students work better offline than with technology. This highlights the need for differentiation when offering mobile learning activities.

4.2.2 Is there a change in attitude towards Mathematics when mobile technology is used for learning math?

There was a slight positive change in students' enjoyment, self-confidence and value of mathematics a month after the intervention has started. Wu et al. (2006) with its day-long session had the same findings. However, these gains have reversed in direction by the end of the intervention. One possible reason is that the increase in scores during the early days of the intervention is mainly due to novelty effects. As students progressed through the intervention, and having taken the same instrument the third time in three months, it might be possible that they have been more reflective of their attitudes towards mathematics and this was echoed in their self-evaluation.

Another possible reason is that, the exposure to the tablets was not enough to yield a permanent change. As with Miller and Robertson's (2010) findings, 3 months of mobile learning did not result to a change in attitudes towards mathematics. Glimpses of negative attitudes towards mathematics are noted in the interviews as students repeatedly compared the activities they have with the tablets with to their usual maths class, often quoting it their usual maths session as boring and the tablets a lot better. It can be that while students found the once a week activity with the tablet interesting, this does not outweigh their daily experience with maths.

4.2.3 Is there a change in attitudes towards technology when mobile technology is used for learning mathematics?

The results of this study have shown that change in students' confidence with technology and valuation of mobile technology can be dependent on various factors. However, programme fidelity and student characteristics are possible reasons that might have explained the divergence of results.

In the school that had a reduction in their confidence with technology, students started out with high self-evaluation scores. However, the technical breakdowns encountered meant that some class time had been spent on troubleshooting the issues which had affected the round-up session at the end of period. Furthermore, the teacher described the students in this class as students who have issues with self-confidence, problem solving, and working with others. The teacher also noted that almost half the class needed additional support needs while the attitudes scores of this class towards mathematics is also lower than the other class. It could be that the due to these student characteristics, students may not have handled the technical issues presented as well as the participants in another group that also encountered the same issues.

After a systematic search of literature, there was no study that directly explored how the use of mobile technologies affected change in students' attitudes towards technology has been identified. What literature have are end-report evaluations of mobile technology use in mathematics (for example, Huang et al., 2012). A similar pattern of decrease in attitudes toward technology has been found in a computer-based implementation (Yushau, 2006). Yushau explained that possible reason for this decline may be that the system used as part of the intervention is more rigorous and at a higher standard than what students have been used to. Applying this same line of reasoning, it could be that the use of mobile technologies in this study is different from what students might normally use their own mobile technologies. And so, while the findings of the study have pointed to a decrease in students attitudes towards technology, this finding is not entirely negative.. While their confidence scores might have gone down, the design of the activities has let them explore other ways to use technology.

4.2.4 Is there an improvement on mathematics achievement when using mobile-supported math learning activities?

There was an improvement on students' maths test score. The effect size of .47 computed for this study is similar to the meta-analysis of elementary studies on achievement (ES=.48) conducted by Fabian et al. (2014). Some students felt that this new way of doing maths has helped them grasp abstract maths concepts and as a result have helped them remember the concepts being learned.

4.3 Limitations of the study

Several limitations are present in this study. The dependence of the data on self-reports given the age of the participants was a shortcoming. This was controlled by repeatedly discussing with the students what the words meant whenever they have to conduct an evaluation. Students were also encouraged to ask for clarification whenever they're not sure what the question meant which was particularly an issue for the double negative statements.

Other limitations of the study point to the sample size, design and implementation fidelity. The small sample size is a threat to the validity of the results, and so, effect sizes were also provided to give an idea of the magnitude of the difference between the groups investigated. The no-treatment control group is a limitation of the design. While this was not the original intention of this study, it had been particularly difficult to recruit schools willing to involve a control group.

4.4 Implications for future practice, policy and research

This study has a mixture of positive and negative results in using mobile technologies for mathematics and the variation in results means that while mobile learning could be beneficial in some situations, further research is needed to help identify which situations and learning environments it is most suitable to use. The gender differences found in this study occurred implies that there is a need to consider how both genders can be encouraged to engage in mlearning activities. The non-significant findings on effects to attitudes calls for further research with longer implementation. This study was implemented as a once a week activity over a period of three months, and adopted active, collaborative learning activities. If the timeframe and frequency has been changed, what effect would this have to students' attitudes? If the activities were different, would students still find it better than their regular maths?

In this implementation, we have opted to use various brands of more affordable tablets on the Android operating system and provided our own wireless network and this raises budget issues and other practical concerns. Should the schools invest in these technologies or should it harness what students already have and instead have a policy for Bring-Your-Own-Device (BYOD)? Where devices vary, what technical skills teachers should have to help students carry on with tasks should technical issues arise? Schools might have existing wireless connectivity but there is still the question of how well existing infrastructure will work with an influx of wireless devices. The questions above are just a few from the list of technical considerations that needs to be addressed before implementing these technologies in the classroom.

The field of mobile learning is fairly new and the technology that supports it is changing very fast. The issues and questions raised here are among the many questions in this highly evolving field.

5. Conclusions

This study set out to investigate the effects of using tablet devices for mathematics learning in terms of student attitudes, perception and their achievement. The design of the activities carried out in this study featured mobile technologies being used for active, collaborative learning activities. It also presented how these technologies can be used to allow students to engage with their environment as they explore maths concepts. We found a modest difference in students’ performance in maths test but the weekly use of the tablets had not shown an increase in students overall attitudes towards mathematics.

The findings that were presented suggest that just as the use of mobile technologies elicited positive responses from the students but technical issues can be disruptive of the learning activities. While there are advantages in adopting these technologies in the classroom, it is worth underlining how the design of the activities, the technical breakdowns and learner characteristics can make a difference in results. Just as it is important to consider the functionalities of the device and how it can be used to integrate to existing curriculum, it is also important to consider how the design of the activities fit with learner characteristics.

Ultimately, it is the teacher not just the technology that drives the change in the classroom. Program fidelity issues, technical breakdowns, and student characteristics and learning designs are all tasks that fall on the teacher and it would be worthwhile addressing how teachers are being trained to target those issues aside from just being trained to use new technologies. The research has not addressed the role of the teacher in this implementation and this is a gap being considered in a further study.

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